Biodiversity and Conservation **4**, 220–232 (1995)

Minilivestock: from gathering to controlled production

JACQUES HARDOUIN

Tropical Animal Production Unit, Institute of Tropical Medicine, 155, Nationalestraat B-2000 Antwerpen 1, Belgium. BEDIM, Unité de Zoologie Générale et Appliquée, Faculté des Sciences Agronomiques, 2 Passage des Déportés, B-5030 Gembloux, Belgium

Received 6 January 1994; revised and accepted 15 October 1994

Many small animals, vertebrates and invertebrates, homoiotherms (endotherms) and poikilotherms (ectotherms), are used by man since he gathers, hunts or collects them in the wild. When bred under controlled conditions in captivity, these animals are called 'minilivestock', a term also used for those small species that are little known in animal production. To qualify as minilivestock, animals must have a potential benefit either nutritionally for food or economically for animal-feed or revenue, and currently not being utilized to their full potential. Rodents are eaten in Africa and Latin America. The guinea pig (*Cavia porcellus*) is considered a particularly efficient meat source. Giant African snails (*Achatina* spp) are highly prized as food in West and Central Africa and Asia, and are produced commercially. Annelids living in litter and manure convert vegetable refuse to animal protein which can be used as feed for pigs and poultry. There is a continuous demand for frogs' legs on the international market and also for many species of insect, alive or mounted. The development of minilivestock will contribute to meeting human needs and will also protect the environment from excessive harvesting.

Keywords: minilivestock; food; animal feed; revenues; rodents; snails; manure-worms; insects; health hazards

Introduction

The word 'microlivestock' was introduced around 1984 by Noel Vietmeyer (see also Vietmeyer, 1991), senior scientist on the Board on Science and Technology for International Development of the National Research Council, USA. His objective was to draw to the attention of the world's scientific community, that there are many animal species with a promising future and/or possible economic use. He listed at the time, under the heading 'microlivestock', many species that were well known in certain places but totally ignored as a protein source by most animal production specialists in industrialized countries. They included edible rodents, guinea pigs, capybara (*Hydrochoerus hydrochaeris*), pigmy hog, microbreeds of cattle, goat or sheep, dwarf deer, quail (*Coturnix coturnix*) and lizards (*Reptilia: Squamata*) but also well known and long domesticated species such as rabbits (*Oryctolagus cuniculus*) and bees (*Apis mellifera*).

Microlivestock are often equated with 'unconventional livestock', a term already used in about 1979 by W. Treitz (personal communication) who now says that the description 'unconventional' is even more confusing than 'microlivestock'. The present author decided personally to modify the terminology, adopting in French the word 'miniélevage' = 'minilivestock' instead of 'microélevage' = 'microlivestock' (Hardouin, 1986). *MICRO*-livestock should properly comprise organisms of microscopic size such as yeasts, fungi or bacteria, which are high-quality protein sources and which can be produced under controlled conditions.

In contrast, *MINI*-livestock should encompass animal species that are normally smaller than sheep, goats, pigs, rabbits and poultry but are used in certain localities as food, animal feed or sources of revenue. This means that dwarf sheep are not minilivestock but small ruminants such as guinea pigs are, as they are traditionally eaten in South America.

The term minilivestock also includes small vertebrates (poikilotherms or ectotherms) that can be used as animal feed or food, such as certain snakes, lizards and frogs. By some unproclaimed agreement fish, despite their great importance as a food source, are not considered to be minilivestock and therefore are not covered in this paper.

Invertebrates can be considered as minilivestock if they are used as food, animal feed or as sources of revenue and are kept for one of these purposes by humans. Termites (*Macrotermes* spp) destroying huts are not minilivestock. However, when favourable conditions are created so that their larvae can be collected and fed to semi-domesticated guineafowl (*Numida meleagris*), they can be considered as such. The same applies to land snails, earth- or manure-worms, maggots (dipterous larvae), butterflies and other insects (DeFoliart, 1995). It should be noted that the word 'microlivestock' is still sometimes used for these small invertebrate animals and was standard terminology in earlier texts.

In approximately 1987, the European Community Commission was authorized by the European Parliament to launch a general research and development programme based on collaboration between institutions in industrialized and developing countries. Proposals had to be innovative and geared towards development in the field for the benefit of the human race. The microlivestock concept was very novel at that time – at least for most of the scientists and donors from industrialized countries.

At the same time and in several countries, biologists and ecologists were drawing attention to the clear signs of decline of many small animal species in the wild. Ban of capture or sale, or greater enforcement of legislation, were the recommended measures in order to try to halt this (Cooper, 1995). External observers in developing countries had also noticed that the traditional sale points of bushmeat were moving on roadsides, the sale places being found further and further from the towns. Hunting/poaching pressure had remained constant, with the harvesting rate becoming greater than normal production. One possible way of reversing this trend was to attempt to breed and raise (rear) these animals; in other words, shifting from *gathering* to *production under human control*. A research project was prepared as a consequence.

This project, 'Microlivestock as food and feed under semi-urban farming systems' TS2–0263, funded by the ECC/Directorate General XII under the Science and Technology Programme for Development, started in 1990. Under the general co-ordination of the author, the Head of the Tropical Animal Production Unit of the Institute of Tropical Medicine, Antwerp, Belgium, three European countries (Belgium, Germany, Italy), four African countries (Benin, Cameroon, Ivory Coast, Zaire) and the Philippines in Asia, were integrated into the project. Scientific topics were shared between the partners: giant African snails (Belgium, Germany, Ivory Coast, Benin), earthworms/manure-worms (Belgium, Philippines), guinea pigs (Italy, Cameroon) and giant rats (Zaire).

The breakthrough created by the ECC's decision – together with the project's activities and preliminary results, the articles produced and the support that was provided by CTA (Centre Technique de Coopération Rurale et Agricole) and FAO (Food and Agriculture Organization of the United Nations) – allowed many scientists, developers and farmers to initiate relevant work in this field in their own situations. In the meantime, an informal network called BEDIM (Bureau for Exchange and Diffusion of Information on Minilivestock) was created in order to disseminate data on minilivestock through a published Bulletin (see below).

It became evident to the ECC/DGXII authorities that minilivestock should no longer be considered a useless hobby or a fantasy that could be rejected out of hand. On the contrary, demands for advice and assistance or training were increasing. Consequently, it was decided to organize a seminar, by invitation, enabling specified young scientists who were concerned with, or working on, minilivestock, to meet for discussion and to learn from the experiences of colleagues.

Since the whole field of minilivestock was likely to prove too large, it was agreed that the seminar theme should focus on invertebrate farming/ranching. The seminar was held in The Philippines in November 1992 and formulated several recommendations in various fields, one of which concerned terminology. This read as follows:

The seminar recommends

(i) That the term 'minilivestock' be adopted in place of 'microlivestock' which, it is felt, does not give an accurate representation of this new field of animal production.
(ii) That the definition of minilivestock be 'using species little known in animal production'.
(iii) That these animal species include both vertebrates and invertebrates, which can be terrestrial or aquatic by nature, but of a weight usually under 20 kg.
(iv) That these animals must have a potential benefit, either nutritionally or economically, and currently not being utilized to their full potential.

Hence the use in this paper, and generally the trend elsewhere, of the term minilivestock in place of microlivestock.

Edible rodents

A large number of those animals classed as minilivestock are edible rodents. The main ones to date are as follows:

(i) The grasscutter, cane-cutter or cane rat, *Thryonomys* sp. (incorrectly called agouti, correctly called aulacode): distributed throughout tropical Africa. 50–60 cm long, 4–5 kids per litter three times a year, average weight 4–6 kg but up to 8–9 kg. Wild (free-living) populations are declining around towns (Lagos, Cotonou, Lome, Accra) due to a very high demand. Much investigation into breeding; there is a very active research centre in Benin with German assistance (Jori *et al.*, 1995).
(ii) The giant rat or Gambian rat, *Cricetomys* sp. (formerly rat de Gambie, now cricétome): essentially the same distribution as the cane rat but missing from an area near the Gulf of Guinea. Smaller than the grasscutter (43 cm long, 1–2 kg) but has a shorter pregnancy (4–6 weeks versus 2 months) and up to six litters a year, which is an advantage in terms of productivity per head per year. Some research in Zaire and Benin. Very popular.
(iii) The ground squirrel (rat-palmiste, écureuil fouisseur), *Xerus erythropus*: size 30 cm, 1-month pregnancy and three litters yearly. Eaten. No research known.
(iv) The capybara, *Hydrochoerus hydrochaeris* (cochon d'eau), from the swamps, marshlands and flooded grasslands and forests of South America. The heaviest

rodent in the world, weighing 50 kg with a maximum reported of 90 kg, 4–6 young per litter, 5-month pregnancy and 1–2 litters per year. Considered locally as already semi-domesticated. Its productivity in the biotope is claimed to be much higher than that of cattle, sheep, goats or pigs.

(v) Many other South American rodents are also eaten locally, but are mostly unknown to animal production or health officers from Europe, Africa and Asia. They include:
  (a) The true agouti, *Dasyprocta* (cotia): 40–60 cm, 2–5 kg, a good jumper but can easily be kept confined by a wall 1 m high if well fed; 3.5–4 month gestation.
  (b) The true hutia, *Capromys*: probably the first meat Christopher Columbus tasted in the New World, now facing extinction in some islands of the Caraibes. Many species. 20–60 cm, 1–9 kg, some live in trees.
  (c) The mara, *Dolichotis patagonum*: resembles a dwarf antelope or a tall hare. Lives in desert plains of Argentina and in Patagonia; 8 kg average.
  (d) The paca, *Agouti paca*, is not the agouti and was previously classified as *Cuniculus* or *Stictomys*. It is a white-spotted tailless rodent living in lowlands from Mexico to Northern Argentina. Weighs 6–14 kg, one young per litter, probably two births per year, 5-month gestation.

(vi) In the Indian Ocean and the Mascarene Islands, very small insectivores are captured for food or as a delicacy. There have been attempts at breeding these species but no research results have been located.
  (a) *Tenrec ecaudatus*: Mauritius, Reunion, Comores can weigh up to three kg; very prolific, broad ecological requirements.
  (b) *Setifer setosus*: Madagascar, also other islands.
  Very small size, only 100–200 g usually. Prolific, apparently with a potential of 25 kids per litter of which 10–15 are usually weaned in the wild.

Edible frogs

Frogs are cold-blooded (ectothermic) vertebrates that can be classified as minilivestock, as they are terrestrial during their adult life and represent a potential source of revenue or food. Frogs' legs are an important food item in Europe. Contrary to what is usually believed, all the 12 countries of the European Economic Community except Ireland import and consume frogs legs, although 80–90% of the import trade involves France, Belgium and Luxembourg, followed by the Netherlands and Italy. The annual net import is worth $18–44 million US (Hardouin, 1994). This high value has been prompted by a continuing demand which could no longer be met by domestic production. Native populations of frogs in some European countries are at present threatened and hence totally protected from collection, transport and sale. Uncontrolled gathering in the wild in Asia has already led to an export ban in some countries (e.g. India) but trade continues in others (e.g. Bangladesh, Indonesia, Turkey). Brazil is known to run commercial frog farms, and frog 'ranches' appear to be feasible in many tropical countries, including African ones.

Most of the edible frogs belong to the genus *Rana*, and the local species used in the past in France, Belgium and Italy were mainly *R. esculenta*, *R. lessonae*, *R. ridibunda* and *R. dalmatina*. The adult green European frog (*R. esculenta*) usually weighs 200 g, and its legs which are offered for sale are around 25 g per pair, but this can vary. Attempts have been made to breed European frogs under controlled conditions, but without success, at least in economic terms. Feeding adult frogs is difficult as they need moving, living prey and no commercial edible frog farm, using local species, appears to exist in Europe.

Consumers in the USA and Canada demand a much larger product, not far removed in size from the legs of pigeon or quail. Such a product can be obtained from the American bullfrog *R. catesbeiana*, which when adult weighs 200–400 g. This species has been imported into many tropical countries (e.g. Brazil, Philippines) where it can be bred on commercial farms.

Asian and African countries have their own native species of amphibian, many of which are edible and often sold to local restaurants for consumption by foreigners as 'European frog legs' (Negroni and Farina, 1993). However, all are captured in the wild without any consideration for the equilibrium of the environment. The output usually exceeds the net quantity available to keep the population stable. Nevertheless, it is likely that semi-intensive frog-ranching schemes could be launched with local species in many tropical African countries (e.g. Cameroon, Benin, Ivory Coast, Burundi) with a relatively simple infrastructure and a standing export market to Europe. Several native species of amphibian are known to be appropriate for sale and consumption – for example, *R. tigerina* (Asian bullfrog) in India or Bangladesh.

It is worthy of note here that the world-record size for a frog is attained by *R. goliath*, which lives in the humid forests of Cameroon near the ocean; its adult weight can reach 3 kg and its length 30 cm, i.e. it is of a size not far removed from that of a rabbit.

As is mentioned elsewhere (Cooper, 1995), a number of legal and ethical factors have to be considered when developing minilivestock. In the case of frogs, there has been considerable public outcry about the methods used for killing (Watkins 1986) and this is one of the points that must be taken into account when encouraging their utilization.

Edible snails

Invertebrates collected in the wild for human nutrition or for sale are also classified as minilivestock. Examples are snails, earth- and manure-worms and insects. A characteristic of all these species is that there appear to be possibilities to organize production techniques to meet demand and to generate income, while at the same time reducing hunting or poaching pressure on wild (free-living) populations.

Vietmeyer's book (1991), which is an accepted reference text on minilivestock, surprisingly omits invertebrates with a promising economic future such as snails, earthworms and insects; however, the author agrees that they belong to the group (Vietmeyer, personal communication).

It is within the Phylum Mollusca that the biggest terrestrial invertebrates are to be found. Snails represent for many people an important and traditional protein source and have probably done so for centuries. In West Africa, where some species are indigenous, giant African snails are often considered one of the best sources of bushmeat, although they are not acceptable to some groups (see Cooper, 1995). The taxonomy of these snails is not very clear; confusion exists between species and even more between sub-species or varieties. Nevertheless, two genera are well represented in Africa. These are *Achatina* (shell apex rather acute, elongated shape, usually large clutches (50–500) of small eggs (± 6.5 mm) adult weight 80–250 g) and *Archachatina* (shell apex rather rounded, stocky shape, small clutches (6–15) of large eggs (10 mm or more), usual adult weight 350 g). Both genera live in warm and humid biotopes where they feed on forest litter or organic refuse.

They are collected for direct consumption or sale. The demand has always been high, and there is evidence that the gathering pressure is increasing so that some wild populations have totally disappeared. Hence the justification for controlled production. A similar thing has happened in the recent past in Europe, where species such as *Helix pomatia* (20–50 g) and *Helix aspersa* (5–15 g) declined in numbers in the wild and were consequently protected by law. The creation of snail-production enterprises, using commercial feeds, was an inevitable sequel.

The distribution of the various species of snail has been investigated, and it is known that *Archachatina marginata* is abundant in Nigeria where it is highly appreciated as food (Ajayi *et al.*, 1978; Imevbore, 1990). *Achatina achatina* is eaten in the Ivory Coast where *Archachatina ventricosa* also occurs and the latter is accepted as food in some places. The literature mentions the consumption of *Limicolaria* spp. in Nigeria and Benin but no comparable reference has been located for the large heavy *Burtoa* spp. All snails undergo a period of reduced activity – hibernation in winter for the European species or aestivation in the dry season for African and Mediterranean snails. Research on continental *Helix* has shown that a drop in temperature and variation in day length are required for successful reproduction. *Achatina* and *Archachatina* spp. submitted experimentally to permanent wet and humid conditions have been able to lay eggs without a rest period (Stiévenart, 1992).

The story of *Achatina fulica* deserves attention. This species, indigenous to East Africa, has been introduced into several tropical countries including South-East Asia and Central America, very often with the aim of biological control of local snails that are considered detrimental to agriculture. In all places where it has been introduced *A. fulica* has become a more troublesome agricultural pest than its supposed competitor. It also appears that the Japanese authorities deposited *A. fulica* in many islands of the Pacific Ocean during the Second World War, as a potential meat source for castaways.

More recently, *A. fulica* has been identified in West Africa following its uncontrolled introduction and escape from gardens. It is known to be present in the Ivory Coast (from south to north) and in Benin. Unfortunately, a call for attention and action to be taken over this possible new agricultural pest has not resulted in any official monitoring measures, in spite of the risk it presents. Paley and Mead (1993) reported recently that not only *A. fulica* but also *Limicolaria aurora*, which is endemic to West Africa, has spread to Martinique in the French West Indies.

Feeding on leaves or plant refuse, snails produce a source of protein for local people. It does not take long for domestic pigs to become accustomed to eating live snails, including the shell; such supplementation of the diet can improve the performance of free-roaming or farmed pigs and at the same time reduce the hard currency expense of imported fish- or meat- and bone-meal. Snails can thus serve both as food and as a source of animal feed.

Intensive production of snails is practised in many parts of the world. In recent years, new methods of husbandry, including measures for the diagnosis and prevention of disease, have been promulgated (Food and Agriculture Organization, 1986; Cooper and Knowler 1991).

Manureworms ('Earthworms')

Earthworms are well-recognized as a component of the soil biomass, participating in organic matter cycles. Their possible use as minilivestock has been reviewed recently

(Vorsters, 1992), but basic knowledge of their behaviour and biology has existed for many years (Bouché, 1972, 1977; Edwards, 1983; Sims and Gerard, 1985; Reinecke and Viljoen, 1988).

These invertebrates belong to the Phylum Annelida, Class Oligochaeta. They are hermaphrodite and their reproduction begins with a mutual exchange of spermatozoa during copulation of two individuals. The eggs ('cocoons') that are laid require 17–42 days to hatch, with an average of 1.0–2.7 hatchlings per cocoon; juveniles grow rapidly in an appropriate substrate, composed of litter, remains of plants, animal droppings, bacteria, yeasts and fungi. This explains why the terminology adopted is often 'manure-worm' and 'vermiculture'.

The behaviour and ecology of worms have been analysed by Bouché (1972), who divided the annelids in three groups:

(i) Epigeic species: litter dwellers–mesophagous, living at the surface of the soil, very mobile, usually red- to rosy-coloured, with a high reproduction rate.
(ii) Endogeic species: horizontal burrowers–macrophagous, no cutaneous pigmentation, small size, moderate reproduction rate.
(iii) Anecic species: deep burrowers–macrophagous, brown to black, highly contractile with possible rapid retreat; moderate size; type species *Lumbricus terrestris*.

Commercial production of animal protein is based on the use of epigeic species of worm such as *Eisenia fetida*, *Eudrilus eugeniae*, *Perionyx excavatus* and *Dendrobaena veneta*, the growth to adult stage of which requires respectively 60, 45, 28 or 65 days at 25°C and 70–80% moisture in the substrate.

Techniques for high production have been recently developed (Vorsters, 1992), but the results are dependent on the rearing conditions. An optimal density for a maximal biomass production exists, which means that a yield decrease occurs if the offspring are not removed in time, notwithstanding good substrate and adequate ecological conditions. Harvesting the worms needs careful organisation. This can be achieved by forming a pyramid of the substrate and gradually removing thin layers, so inducing the worms to move away to avoid the light. Simplified methods can be used if the produce has only to be offered to poultry or pigs, as these animals will sort out for themselves what they want. Preliminary results in tropical Africa indicate that live *E. eugeniae* can be used as food for young chicks without any depressant effect on growth. On an experimental basis, a daily production of 1 kg fresh worm biomass on a 25 m^2 substrate was obtained and provided high quality protein supplement for 50 chickens (Vorsters *et al.*, 1992).

Vermiculture is no longer a dream, and the manure-worm can even be considered a dual-purpose minilivestock species, since not only is the biomass produced of very high value, but so is what remains. Fresh substrate leaves a residue after ingestion and digestion by the worms and this casting or 'vermi-compost' is an excellent organic fertilizer that improves poor arable soils by its chemical components and also (particularly) by its humic value and consequent improvements to soil texture and structure.

The storage of worms has recently been investigated in Cuba. Various substrates based on a high proportion of bagasse, together with the worms, are placed in empty petrol drums that are filled afterwards with molasses, without water. This form of silage can be kept under tropical conditions for some months; it is provided in this form to pigs and is eagerly eaten (Perez, personal communication).

In a totally different context, it is also known that earthworms can play a role in de-polluting urban wastes, making compost from organic residues and concentrating heavy metals in their body. The worms cannot be used as feed in these circumstances, but they play an interesting and beneficial role in the purification of rubbish and the breakdown of some dangerous pollutants.

Insects as food

The consumption of insects is commonplace in many parts of the tropical world (Mercer, 1993a). Insects are eaten in their larval stage (for example, caterpillars of the Coleoptera or beetles), or in their adult form (grasshoppers, locusts and winged reproductive termites – Orthoptera and Isoptera), as is frequent throughout Africa. Two coleopterous insects in particular are considered important as food in Sarawak, Malaysia; the sago grub *Rhynchophorus ferrugineus* (Curculionidae) and the larva of the borer *Hoplocerambyx spinicornis* (Cerambycidae). A very wide range of insects is eaten in Papua New Guinea including the larvae of beetles, mayflies (Ephemeroptera), wasps (Hymenoptera), and locusts and grasshoppers. Traditional consumption involves eating the animals raw, boiled or roasted. It is well recognized that insects can be bred quickly, using fewer resources and being cheaper than producing conventional farm animals (Mercer, 1993b).

Entomophagy by humans is usually considered by food and agricultural scientists to be a relic of the Dark Ages and indicative of underdevelopment. However, the nutritional value of insects attracted the interest of the US National Aeronautics and Space Administration, thus bringing the topic fully into the modern age. In the context of space travel insects have the advantage as food of containing high concentrations of energy and protein, and of leaving virtually no waste parts which need to be stored and brought back to earth (DeFoliart, 1989).

Insects are well known as important agents of pollination and as producers of honey and wax. The keeping of bees (*Apis mellifera*) is very well documented and widely practised; hence apiculture and bees are implicitly excluded from the category of minilivestock.

Insects as animal feed

Termites (genera *Acanthotermes*, *Macrotermes* and others) are abundant in warm climates, and the damage they cause to timber, furniture and fencing poles can be substantial. Termite larvae, however, have been used for years in villages as a natural supplement for young chickens or guineafowl (*N. meleagris*), usually by breaking open an active termitarium and putting part of it, including the moving larvae, in with the poultry. Recent attempts in Togo to produce living termites under controlled conditions proved successful (Farina *et al.*, 1991). A jar is filled with very dry leaves and straw, pieces of soil are added and sprayed with water; then the jar is put upside-down over a hole made in an existing termitarium. The jar is protected against the sun by insulation, preferably moistened. The yield (crop) consists of termites which invade the jar and eat the leaves and straw. Harvesting can take place after 2–3 weeks when the contents are given to the birds.

A simplified technique has even been described from Burkina Faso (Ouibga, personal communication) where cattle dung is mixed with straw and soil in an earthenware jar and placed upside down anywhere on the ground. Termites quickly locate this new lignofibrous source of food, colonize it and thus become available for the villager's poultry.

Fly larvae (maggots) have recently been considered for controlled production in order to improve the productivity of chickens and guineafowl. The method uses (for instance) rumen contents mixed with other by-products e.g. traditional brewery draff or blood collected at the slaughterhouse. Water is sprayed daily in the Sahelian biotope. After 2–3 days the substrate is found to be full of maggots which can then be used to feed poultry (Hardouin, 1993). Similar experiments undertaken in West Africa used pig, rabbit or quail (*Coturnix* sp.) droppings which became colonized by flies and yielded maggots within a few days. The insects involved were identified as *Musca domestica* and *Sarcophaga* sp. (Vorsters, personal communication).

Mosquitoes can also be a protein source; there is a valuable trade in farmed larvae in Hong Kong. Larvae of *Chironomus* sp. (Diptera: Chironomidae) are grown on chicken manure put on fields before submersion. Harvesting is carried out after 20–25 days. Cleaned larvae are sold as feed for fish culture farm (Pang-Chui and Kai-Keung, 1980).

Insects as a source of revenue

As mentioned earlier, minilivestock can provide a source of revenue. This is the case when insects are bred and sold for collections, the art trade, simulated tropical exhibits or insectaria. Insect 'farming' has become a viable and environmentally sound enterprise in Papua New Guinea (Clark, 1993), where the government considers it as a development tool for remote villages in forest areas. The success of the operation is linked to the managerial capacity of the scheme, which is focused on a non-profit making agency, responsible for the training of farmers and marketing of the insects. The most popular species of butterfly farmed (ranched) and sold in Papua New Guinea are the common birdwing *Ornithoptera priamus*, *Papilio ulysses* and *Graphium weiskei*, but the demand is high also for stick and leaf insects (Order Phasmida) and some of the larger spectacular beetles. Butterfly farming in Papua New Guinea has been scientifically assessed by the University, which reported excellent results. Rainforest butterflies can be encouraged and harvested through a process of habitat protection, or even habitat creation. Nectar sources have to be provided for the adult butterflies as well as food plants for the caterpillars. The environment and the flora have consequently to be carefully monitored and managed. It is worth noting that the villagers involved in the scheme were already well aware of the relationships between insects and plants, and they quickly became staunch supporters of the concept of protecting the environment, which is the key to sustainable revenues (Mercer, 1993a).

The international demand for tropical butterflies and other insects has produced a strong and active market. The current trade has been estimated to be between $10–20 million US annually (Vietmeyer, 1983).

Silk production is as well known as honey production, and both are extremely well documented. Thus the silkworms, *Bombyx* spp, are not considered to be minilivestock. However, it should be mentioned that by-products of the processing of silk can be used as animal feed.

Health hazards

Very little is yet known, unfortunately, about the health aspects of minilivestock, be it their own diseases or their role as reservoirs or vectors of infections and diseases of humans and domestic animals. This is an important area that warrants more research.

Rodents are often hosts of zoonoses – diseases transmissible to humans – (Cooper, 1985), such as salmonellosis, leptospirosis and yersiniosis (plague). Parasites may also be significant. Joint investigations between Kinshasa and Antwerp have identified for the first time the nematode *Capillaria hepatica* from the giant rat *Cricetomys*. This rodent can also be infested with the cestodes *Megittina*, *Taenia taeniaeformis*, *Cysticercus fasciolaris* and *Cyathospirura scurati*. It is generally accepted that the risks of transmission of such parasites to consumers are very limited on account of the traditional cooking and processing techniques adopted – usually prolonged smoking or boiling. However, dressing of the carcass or cleaning of internal organs can cause unintentional wounds, or eggs of parasites may fall on the ground where young children can come into contact with them. Sporadic infestation of humans is possible; the effectiveness of treatment is then very doubtful and undocumented (Kumar, personal communication).

Publications on diseases of amphibians do not, generally, discuss the health threats associated with eating these animals (Reichenbach-Klinke and Elkan, 1965; Williams, 1991). Nevertheless, there have been reports of contamination of frogs' legs by *Salmonella* and other microbes. Many micro-organisms can cause disease or death in amphibians while others appear to be asymptomatic. Some can be significant when frogs are bred or kept in captivity. For example, 'Red-leg' of frogs is frequent; it is caused by the bacterium *Aeromonas hydrophila* which occasionally can cause disease in humans. Many protozoan parasites have been identified from bactrachians – for example, *Trypanosoma rotatorium*, *T. andersonia*, *Hexamita intestinalis* and *Giardia agilis*. Even viruses can infect amphibians and may affect the animals' health; the Lucké renal adenocarcinoma was recognized long ago in both free-living and captive leopard frogs (*Rana pipiens*) (McKinell, 1969) and recently Cunningham and colleagues (1993) reported unusual mortality associated with poxvirus-like particles in *R. temporaria* in England and Wales.

A review of parasites of giant African snails and their transmissibility to poultry or pigs appeared recently (Raut, 1993). The ciliate protozoon *Trichodina achatinae* colonizes *Achatina zebra*, which can also be host to the microsporidian protozoon *Plistifora husseyi*. Many rhabitoid nematodes may be seen in the gut of *Achatina fulica*. Cases of eosinophilic meningo-encephalitis in humans due to *Angiostrongylus cantonensis*, the rat lungworm, associated with *Achatina fulica* are known from Asia (Alicata, 1988) but the risk is likely to be slight if hygiene is good (Cooper and Mews, 1987). Akinboade and colleagues (1980) warned that enteric bacteria on giant snails might present a threat to humans and stressed that this should be taken into account when considering these animals as a food source. The diseases and pathology of farmed molluscs are discussed in some detail by Cooper and Knowler (1991).

Snails can be vectors of human diseases: for example, *Schistosoma mansoni*, one of the causes of schistosomiasis (bilharziasis), is transmitted by the freshwater snail *Biomphalaria glabrata* which seems to act as an intermediate host.

Certain internal parasites of birds and mammals are transmitted through earthworms – for example, the larval stages of the cestode *Amoebotaenia cuneata* in *Pheretima* spp. The nematodes *Heterakis* and *Ascaridia* also use earthworms as intermediate (paratenic) hosts. Other examples have been recently reported (Spiridonov, 1993).

Viable bacteria, for example *Escherichia coli* and *Bradyrhizobium japonicum*, were recently found coexisting with developing embryos in cocoons of the earthworm *Eisenia fetida* (Zachman and Molina, 1993) and could be significant.

The bacterial flora of raw materials ingested by *Lumbricus* spp. changes qualitatively and quantitatively during passage through the worm's intestinal tract. However, the survival pattern differs between the species of Gram-negative bacteria present: *E. coli*, *Enterobacter cloacae*, *Pseudomonas putrida* and *Aeromonas hydrophila* (Pedersen and Hendriksen, 1993). Transmission of bacteria from domestic animals to earthworms is possible but the next step (from earthworms to poultry or pigs) has not yet been fully investigated.

It is, perhaps, incongruous to be considering disease of flies (Diptera) when general hygiene recommendations throughout the world are to destroy these insects. Nevertheless, when advocating maggot production one should consider the risks of disease transmission to domestic animals and these insects could be a significant source of micro-organisms.

Any living organism, from mammal to invertebrate, can be infected by micro-organisms or parasites. In addition predation can be a problem. As a result economic losses can occur when animals are kept for food, feed or revenue. This, however, should not discourage one from embarking on minilivestock production, as the risks are probably no greater than those associated with the husbandry of such species as cattle, pigs or poultry. Research in this field remains limited, but the trend could quickly be reversed by small, in-depth, investigations. In the meantime, care should be taken to protect the human consumer and to introduce appropriate health precautions. Consultation with medical and veterinary colleagues is recommended at an early stage (Cooper, 1995; Kock, 1995).

Conclusions

Embarking on the production and use of minilivestock is a challenge. One has not only to find solutions for still unidentified problems and to select key parameters for a new type of production, but also one is faced with people who are sceptical, who believe that there is no truth outside their own field of competence, who are decision-makers but ill-informed, or who are currently training young generations for the future using the arguments of the past. The way forward is not easy, is often even frustrating, but nevertheless fascinating and stimulating.

In most cases new minilivestock production systems are best suited for small procedures; for peasants who are unable to afford investment; for people with backyard activities as their sole future; for inhabitants of remote areas; in short, for the poor.

Scientific understanding of minilivestock is increasing and one can foresee that people in tropical and developing countries could start producing meat through a new approach, based on sustainability, on protection of the environment, on rational use of local species and on high demand. Moreover, there are instances where by-products of minilivestock production can be used for soil improvement, thus opening up new possibilities for the integration of livestock and agriculture. One of the constraints is the apparent lack of information and data; in other words, the quasi-absence of publications in this field. This means that a duty of specialists in various subsectors who are involved with minilivestock is to disseminate knowledge by publications in scientific and technical journals and in lay periodicals.

In order to help fill this gap the CTA and the FAO decided in 1992 to produce a semestrial bulletin on minilivestock; the BEDIM bulletin is available free of charge from either organization.

Minilivestock have a great promise. They are, however, still the concern of only a limited number of people, scientists and developers, who have confidence in the opportunities that these animals offer. Being in the forefront is never easy; reluctance and even opposition by others have never halted the progress of scientific knowledge or development and they are unlikely to do so in the case of these new and important species.

Acknowledgements

I should like to express my gratitude to Professor John E. Cooper who kindly invited me to contribute this paper for the Special Issue and who greatly improved my manuscript.

References

Ajayi, S.S., Tewe, O.O., Moriarty C. and Awesu, M.O. (1978) Observations on the biology and nutritive value of the African giant snail *Archachatina marginata*. *East Afr. Wildlife J.* **16**, 85–95.
Akinboade, O.A., Adegoke, G.O., Ogunji, F.O. and Dipeolu, O.O. (1980) Bacterial isolates from giant snails in Nigeria, *Vet. Record* **106**, 482.
Alicata, J.E. (1988) Angiostrongylus cantonesis and eosinophilic meningitis. *Lancet* **ii**, 1367–8.
Bouché, M.B. (1972) Lombriciens de France; Écologie et systématique. *Ann. Zool. Ecol. Anim.* INRA, France; numero hors serie.
Bouché, M.B. (1977) Stratégies lombriciennes (in soil organisms as components of ecosystems). *Ecol. Bull.* **25**, 122–32.
Clark, P. (1993) Organization and economics of insect farming Proc. Seminar Invertebrates (Minilivestock) Farming, EEC/CTA/IFS/DMMMSU/ITM, the Philippines, pp. 25–32.
Cooper, J.E. (1985) Medico-veterinary collaboration. *Tropical Doctor* **15**, 187–91.
Cooper, J.E. (1995) The role of birds in sustainable food production. *Biodiv. Conserv.* **4**, 266–80.
Cooper, J.E. and Knowler, C. (1991) Snails and snail farming: an introduction for the veterinary profession. *Vet. Record* **129**, 541–9.
Cooper, J.E. and Mews, A.R. (1987) Health hazards from giant snails. *Vet. Record* **120**, 506.
Cunningham, A.A., Longton, T.E.S., Bennet, P.M., Drury S.E.N., Gough, R.E. and Kirkwood, J.K. (1993) Unusual mortality associated with poxvirus-like particles in frogs (*Rana temporaria*). *Vet. Record* **133**, 141–2.
DeFoliart, G.R. (1989) The human use of insects as food and as animal feed. *Bull. Entomol. Soc. Amer.* Spring, 22–35.
DeFoliart, G.R. (1995) Edible insects as minilivestock. *Biodiv. Conserv.* **4**, 306–21.
Edwards, C.A. (1983) Earthworms, organic waste and food. *Span* **26**, 106–8.
Farina, L., Demey F. and Hardouin, J. (1991) Production de termites pour l'aviculture villageoise au Togo. *Tropicultura* **9**, 181–7.
Food and Agriculture Organization (1986) *Farming Snails I.* Rome: FAO Economic and Social Development Series.
Hardouin, J. (1986) Mini-élevage et sources méconnues de protéines animales. *Ann. Gx* **92**, 153–62.
Hardouin, J. (1993) Termites and maggots use as feed: preliminary information. Proc. Seminar Invertebrates (Minilivestock) Farming. EEC/CTA/IFS/DMMMSU/ITM, The Philippines, p. 163.
Hardouin, J. (1994). Commerce international des cuisses de grenouilles dans la CEE de 1988 a 1992. (Submitted). *Bull. Rech. Agron. Gembloux* **29**(2), 217–45.
Imevbore, E.A. (1990). Carcass evaluation and nutritive value of some popular edible molluscs in Nigeria. *Die Nahrung* **6**, 549–53.
Jori, F., Mensah, G.A. and Adjanohoun, E. (1995) Grasscutter production: an example of rational exploitation of wildlife. *Biodiv. Conserv.* **4**, 257–65.

Kock, R.E. (1994) Wildlife utilization: use it or lose it – a Kenyan perspective. *Biodiv. Conserv.* **4**, 241–56.

McKinell, R.S. (1969) Lucke renal aderocarcinoma: epidemiological aspects. In *Tumors of Amphibians* (M. Mizell, ed.) pp. 254–60. Berlin: Springer.

Mercer, C.W.L. (1993a) A butterfly ranching trial in Papua New Guinea. Proc. Seminar Invertebrates (Minilivestock) Farming. EEC/CTA/IFS/DMMMSU/ITM, the Philippines, pp. 33–40.

Mercer, C.W.L. (1993b) Insects as food in Papua New Guinea. Proc. Seminar Invertebrates (Minilivestock) Farming. EEC/CTA/IFS/DMMMSU/ITM, the Philippines, pp. 157–162.

Negroni, G. and Farina, L. (1993) L'élevage de grenouilles. *Cahiers Agriculture* **2**, 48–55.

Paley, L. and Mead, A.R. (1993). Les deux redoutables escargots geants africains a la Martinique. *Phytoma* **44**, 48–50.

Pang-Chui Shaw and Kai-Keung Mark (1980) Chironomid farming – a means of recycling farm manures and potentially reducing water pollution in Hong Kong. *Aquaculture* **21**, 155–63.

Pedersen, J.C. and Hendriksen, N.B., (1993) Effect of passage through the intestinal tract of detritivore earthworms *Lumbricus* spp. on the number of selected Gram negative and total bacterial. *Biol. Fertil. Soils* **16**, 227–32.

Raut, S.K. (1993) Known parasites of giant African snails and their transmission to poultry or to pigs. *BEDIM* **2**.

Reichenbach-Klinke, H. and Elkan, E. (1965) *The Principal Diseases of Lower Vertebrates*. London, New York: Academic Press.

Reinecke, A.J. and Viljoen, S.A. (1988) Reproduction of the African earthworm *Eudrilus eugeniae* (Oligochaeta) cocoons. *Biol. Fertil. Soils* **7**, 23–7.

Sims, R.W. and Gerard, B.M. (1985) Earthworm Synops. *Brit. Fauna* **31**, 1–171.

Spiridonov, S. (1993) Parasites of earthworms as possible threat to vermiculture. *BEDIM* **2**(2), 11–12.

Stiévenart, C. (1992) Biology of some *Achatinidae* known as edible snails. Proc. Seminar Invertebrates (Minilivestock) Farming, EEC/CTA/IFS/DMMMSU/ITM the Philippines, pp. 145–54.

Vietmeyer, N.D. (1983) *Butterfly farming in Papua New Guinea*, Managing Tropical Animal Resources Series. National Research Council, Washington DC: National Academy Press.

Vietmeyer, N. (1984) Du bétail pour les sans-terre. *Ceres 98*, **17**, 43–6.

Vietmeyer, N. (1991) *Microlivestock: little-known small animals with a promising economic future*. National Research Council, Washington DC: National Academy Press.

Vorsters, A. (1992) Biology and production of manure worms. Proc. Seminar Invertebrates (Minilivestock) Farming, EEC/CTA/IFS/DMMMSU/ITM, the Philippines, pp 53–7.

Vorsters, A., Adjovi, A. and Demey, F. (1992) Production of earthworms as a source of protein for chicken feed. The use of *Eudrilus eugeniae* and *Eisenia fetida* in tropical conditions. *Newsletter of Africa Network for Rural Poultry Development*.

Watkins, V. (1986) *An Investigation into the Frogs' Legs Trade*. Report Series L861001. London: World Society for the Protection of Animals.

Williams, D.L. (1991) Amphibians. In *Manual of Exotic Pets*. P.H. Beynon and J.E. Cooper eds. Cheltenham: British Small Animal Veterinary Association.

Zachman, J.E. and Molina, J.A.E. (1993) Presence of culturable bacteria in cocoons of the earthworm *Eisenia fetida*. *Appl. Environ. Microbiol.* **59**, 1904–10.